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THE SHORE PLATFORMS OF LORNE, VICTORIA, AND THE PROCESSES OF EROSION OPERATING THEREON

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Abstract

The processes of erosion by which the shore platforms of Lorne (which are comprised in the writer's term 'minor platforms') are being extended landward, reduced vertically and destroyed at their seaward edges, are the subject matter of this paper. The rocks forming the platforms are felspathic sandstones (strictly speaking arkoses) mudstones and shales, and their lithology and geological structure have an important influence on the processes of erosion now at work. Those processes are almost all marine and are described under the headings of quarrying, planing, grooving, flaking, pitting ('honeycomb weathering'), minute furrowing, saucering and water-level weathering.

Introduction

The writer in his paper (1949) on the shore platforms of Lorne, which is situated at Loutit Bay on the southern coast of Victoria (see Fig. 1 of that paper), described the lithology and geological structure of the component rocks of the platforms, the strength and direction of the ocean waves, the contour of the coastline, the character of the hinterland and the general processes of erosion, with the resulting forms of the platforms. That paper should be read in conjunction with the present one, in which more detailed descriptions of the processes of erosion referred to in the earlier paper are given.

The component rocks are of freshwater origin, of Jurassic age, and are mainly sandstones (really arkoses, Edwards and Baker 1943, but the former term is used in the writer's paper referred to above and is retained here) with some shales, that term as in the writer's 1949 paper being used for convenience to include both mudstones and shales. The rocks dip at various angles and have master joints close to the vertical.

Incidentally it may be mentioned that the nomenclature of the platforms used by the writer in the 1949 paper has been changed by him (1950) by substituting for the term 'ultimate platform' the term 'major platform', and for the term 'normal platform' the term 'minor platform'. The minor platform is the narrow platform abutting the coastal cliffs and the major platform is the platform extending seawards indefinitely from the seaward edge of the minor platform. The minor platform as shown by the writer (1949) comprises three divisions running parallel to the coast, the most seaward being the 'rampart', the middle one being the 'depression' and the one abutting the cliffs being the 'abrasion ramp', which in this paper will be referred to as the 'ramp'. (See Fig. 9 of the writer's paper already cited.)

The beach at the head of Loutit Bay has been named by the writer (1949) the 'Erskine Beach' and the minor platforms at Point Grey and between that point and the Erskine Beach have been named by him the 'Point Grey Platform' and the 'Point Grey-Erskine Platform' respectively.

The Processes of Erosion

It may be stated that shingle is scarce except in the narrow channels cut through the rampart and the depression but that sand, although scarce at times, is mostly abundantly available for the rasping of the rocks.

At Lorne the processes of erosion comprise quarrying, planing, grooving, flaking, pitting ('honeycomb weathering'), minute furrowing, saucering and water-level weathering. Pot-hole erosion is very scanty.

Quarrying

This operates on the rampart and along the miniature bays and channels which have been cut through the rampart into the depression, and in some places into the ramp.

Planing

This term is used in this paper to indicate the action of the sea in producing, mainly by sand rasp, smooth rock surfaces. That this action can produce a smooth inclined rock surface such as the ramp is, the writer believes, generally accepted, but there may be some difference of opinion as to whether similar horizontal surfaces can be produced. Since, however, that action is bound up with the processes of minute furrowing, saucering and water-level weathering, the question is most appropriately discussed under those headings, but it may be emphasized that planing may act both vertically and laterally.

Grooving

This occurs mainly along the joints and stratification planes of the rocks, particularly those of the rampart, to a depth and width of a few inches. Grooving in relation to pitting ('honeycomb weathering') is discussed in the section of this paper treating of the latter subject under the sub-section 'Removal of the Pits'. Special forms of grooving are dealt with under the heading 'Minute Furrowing'.

Flaking

Flaking is best observed on the surfaces of the depression and the ramp, particularly where the rocks dip at a few degrees only, which enables erosion to take place along the stratification planes and so prepare the way for the collapse and breaking up of the undermined portion of the stratum.

Pitting ('Honeycomb Weathering')

General Characteristics

Pitting in the rocks of Lorne is widespread and it is a potent agent of erosion, both directly and indirectly. It is mainly of the usual type of 'honeycomb weathering' (Pl. VII, figs. 1, 2, 3).

The pits are almost entirely restricted to the sandstones (which are practically homogeneous rocks) and it may be suggested that this is owing to the great preponderance in area of the sandstones over the shales. This is probably in part true, but the main reason appears to be the greater vulnerability of the sandstones, partly owing to the coarseness of grain and the relative looseness of cohesion compared with the shales, and partly to the fact that there is much more felspathic material in the sandstones than in the shales, as Edwards and Baker (1943, p. 208) have shown in their paper on the Jurassic arkoses of Victoria, the inference to be drawn from that fact being probably the more rapid decay, under any conditions of weathering, of the sandstones.

The pits occur freely on all faces of the rampart and on the depression, especially on that portion of the latter adjacent to the rampart, but are fewer on the ramp. They also occur on the exposed faces of detached blocks of rock whatever inclination any face may have.

Where the rocks in the rampart are scoured by the waves practically continuously no pits form, but where the scour is intermittent owing to low tide then pits occur. This is well shown in some channels with vertical or highly inclined walls (being joint or stratification planes), the lower portions (12 to 18 inches in depth) of the walls being free from pits and the upper portions of the same walls, whatever their height, being pitted.

The sandstones of the depression and the ramp are divided into polygons varying in size from a foot or two in any direction to areas about 10 feet by 12 feet and occasionally about 30 feet by 50 feet. (See Pl. VI, fig. 3, of the writer's 1949 paper cited above.) The boundaries (mainly rectilinear) of the polygons are vertical or nearly vertical joints, which appear in many instances to be an important factor in determining either directly or indirectly the distribution of the pits. Some pits occur actually along the joint (Pl. VII, fig. 1), but oftener they are on one or (usually) both sides of it for a width varying from an inch to three or four inches or more on each side, and this occurs whether the sandstone has been altered or unaltered for a few inches from the joint outward by the introduction of iron oxide which often projects as ribs along the joints. The pits in some areas extend beyond the width mentioned for another few inches, leaving the remainder of the polygons free of pits, or that remainder may be wholly or partly occupied by pits. The reason for the absence of pits from some of the unaltered areas may be that those areas are reduced by other eroding agents too fast to permit of the formation of pits.

Since the rocks at and about low water mark come for longer periods in contact with the sea one would expect the pits to be more abundant on the rampart (where the waves so frequently break) and on the outer (seaward) part of the depression than on the inner (landward) part of the depression and on the ramp and that is what is found.

The calcareous concretions ('cannon balls' and other forms) (Pl. VII, fig. 1) in the rocks have fewer pits than the ordinary bedded sandstones, the reason being that the concretions are more resistant to erosion. The greater hardness of the concretions is apparently owing to the abstraction of calcite from the surrounding sandstone and its transfer to the concretions (see Edwards and Baker 1943, p. 207).

Origin of the Pits

Primarily the pits are owing to the splash of the waves and the spray from the sea to a height of not less than 12 feet above the general level of the depression or of the ramp, but what exactly takes place is difficult to say.

The question has been discussed by C. A. Cotton (1922, at p. 258) in connection with greywacke rocks near Wellington, New Zealand; by Bartrum (1936); and by Hills (1940). Cotton points out that the walls of the 'honeycomb' cells are strengthened by a mineral deposit containing apparently a good deal of iron oxide which is deposited along the walls of closely spaced joints, that the mineral matter so deposited is evidently leached from the intervening areas where the sand grains are loosened by weathering so that they are readily removed by the wind, and it is possible that the chemical actions involved in the leaching and deposition of the mineral matter forming the cell walls are due to salt supplied by sea-spray.

Bartrum (1936, p. 599) agrees in ascribing the honeycombing of coastal rocks as largely to sea-spray and crystallization of sea salts with wind playing the dominant part in the removal of the products of weathering that accumulate in the cell-like hollows, though minor assistance is given by water from spray or rain, particularly in removing the finest particles.

Hills (1940, pp. 28 and 29, and fig. 29, p. 26, 'Honeycomb Weathering in Jurassic Sandstones, Lorne') considers that the pits are due in part to alternate wetting of the rocks by sea-spray and drying out; that the crystallization of salt breaks up the rock in hollows where the spray collects; and that the disintegrated rock particles are removed by the wind.

Thus Cotton, Bartrum and Hills are in substantial agreement as to the general origin of the pits, with Bartrum going more exhaustively into the matter than either Cotton or Hills.

The present writer generally agrees with Bartrum as to the origin of the pits, but would suggest that sufficient allowance has not been made by him as to the effect of the heavy blows dealt to the rocks by the falling masses of water whether of waves or spray. By alternate wetting and drying, by chemical decomposition and perhaps by the crystallization of sea salts, the surface of some of the rocks is doubtless weakened and, to a certain extent, disintegrated in a very irregular manner so that when particles of sea water fall on that surface its weakest portions are liable to be removed, and so incipient hollows may be formed. Once that occurs then the general conditions stated by Bartrum for the development of the pits would apparently apply, but it must be remembered that Bartrum's conclusions are based on the occurrence of pits on gently inclined or sub-horizontal rock surfaces only, whereas at Lorne, the pits are found on horizontal and vertical surfaces and on all surfaces between the horizontal and vertical; hence the direct action of the sea by the blows mentioned above would appear to be the strongest direct agent in the commencement of the pits.

Since also the pits occur on the walls of the channels through the rampart, it would appear that where the rocks are daily not long free from being covered by the sea the removal of the disintegrated fragments by the wind is most improbable. Rather it would seem that the same blows repeated again and again as well as the general swirl of the sea would wash out the loose material as well as tend to direct further erosion of the pits. Where, however, parts of the platform close to the shore are daily long free from the sea, or where, unless at unusually high tides, or in storms, portions of the platforms, or the residuals or loose blocks thereon are perhaps for days at a time free from the sea and so enable the surface of the pits to dry out completely, then the wind is probably the chief agent in the removal of the fine disintegrated portions of the pits. But rain, particularly when heavy, beating directly into the pits must also, especially when the pits are shallow, force the disintegrated material out of the pits as well as helping to bring about that disintegration. However, further investigation on all these points is required.

Removal of the Pits

Where pits are absent from parts of the areas where they occur it is difficult in some instances to say whether they have been formed and have been subsequently removed or whether they have never existed.

Especially on the depression and the seaward portions of the ramp a great many pits are in course of removal (Pl. VII, figs. 1, 2, 3), the mode of which, in the writer's opinion, is by vertical and lateral planation by the sea with perhaps some assistance from water-level weathering as suggested by Edwards (1951). Some details may now be given of the processes at work.

The joints in the rocks largely control the removal. Thus in vertical planation the whole or the greater portion of the pits in a given polygon may be in course of removal downward. All stages in this process can be seen from the commencement to the faint traces of the pits which presage their entire disappearance, leaving a smooth horizontal or slightly inclined plane surface according to the character of the original surface. (Pl. VII, fig. 1.)

In lateral planation the process usually appears to commence along the joints of the polygon, a groove being formed at or immediately adjacent to the joint, the depth of the groove extending to the base of the pits. The sea then works laterally across the polygon and the result again is a smooth horizontal or slightly inclined plane surface. (Pl. VII, fig. 1.) There may be both vertical and lateral erosion working at the same time. (Pl. VII, fig. 3.)

In the way just stated a mass of rock three to four inches thick may be rapidly removed.

Of course, the above statements are more or less generalized, inasmuch as the pits may not extend over the whole of the surface or they may not be along or close to the joints or that the grooving may commence on any part of the surface and extend towards one or more of the joints, but mostly the removal takes place by one of the methods indicated above.

It must be remembered that grooving along or close to the joints can take place by the direct action of the sea without the intervention of pitting.

Causes of the Apparent Cessation or Slowing Down of the Formation of the Pits

Edwards (1951) has remarked on the removal of the pits and it would appear to the present writer from a fairly close inspection of the areas comprised in this paper that the pits on the depression and the ramp are being removed faster than they are now being formed. One would think that as the outer parts of the rampart were reduced laterally as well as vertically by marine erosion, the pits would increase in number landward, but as stated above this is not apparently so and the question therefore arises why that result should ensue.

The depression and the ramp were of course in existence when the pits now thereon were formed and there is no change in the component rock characters, but the forces that brought the depression and the ramp into existence, i.e. as the writer believes, the formation of the channels and small bays in and through the rampart by means of which the sea worked coastwise behind the area now occupied by the rampart, were then not so strong as at present. Presumably those forces have recently gained momentum with the result that the pits are being removed by wave planation faster than they can be formed. In other words, pitting was dominant when the channels and miniature bays were shorter and narrower than at present, but the position may now be reversed. (See also Edwards 1951, p. 48.)

Pitting at an Originally Higher Level

It would appear that the area now occupied by the depression must have been at a higher level at an earlier date. That being so, pitting was no doubt taking place at that level. The formation of those pits would hasten the general lowering of that area owing to their comparatively easy removal. Consequently there would be a downward succession of pits, some of the present ones being doubtless the lineal descendants of the first-formed ones.

Role of the Pits in the Lowering of the Rock Surface

When the pits are so numerous as they are at Lorne they play an important part in the general lowering of the rock surface, directly by the formation of the pits and indirectly by the comparative ease with which the other agents of erosion must remove the pitted rock. These advantages, however, would be somewhat lessened if the walls of the pits were hardened by infiltration of some material (such as limonite or hematite) more resistant to erosion than the sandstones.

Minute Furrowing

Whilst it seems clear that the sea can plane a rock surface evenly down vertically so as to be free from all prominent projections, yet tiny irregularities remain on that surface and at Lorne, on parts of the depression and the ramp, amongst those irregularities are minute furrows which show definitely the detailed action of the sea and the resulting rock surface and which have not hitherto come under the writer's notice. These minute furrows belong to two types of erosion.

The first type, which is well seen on the Point Grey-Erskine Platform and mainly on the depression, consists of furrows generally parallel to and along the lamination planes of the sandstones and to one another. They are not absolutely continuous since they die out but immediately make again in practically the same lines. Neither the ridges nor the furrows would probably as a rule exceed one quarter to three-eighths of an inch in width, while the furrows would probably be little more than one-eighth of an inch in depth. Very fine flakes are peeling off the whole of the rock surface but there is more being shed from the furrows than from the ridges. It is evident that the slightly turned-up edges of the strata favour this mode of erosion which is probably a combination of sand scour and flaking off due to alternate wetting and drying.

A section (Fig. 1) across the strata shows the contour of the surface on a minute scale and this contour is in marked contrast (by reason of its sharp outlines) with the second type of minute furrowing (with rounded outlines) now to be described.

The second type is well developed on the sandstones of the inner portions of the depression and on the ramp about half a mile south-west of Point Grey. These furrows doubtless occur at many other points. They are usually one-eighth to one-quarter of an inch (but occasionally up to one-half of an inch) deep and about one-eighth to one-half of an inch (but occasionally up to one inch) wide with the ridges of the same widths, and both ridges and furrows having rounded outlines. The furrows may be parallel to or at any angle to the strike of the rocks, and in places it can be seen exactly how the sea has worked. For example, as shown in Fig. 2, the furrows and ridges are seen to bend around and follow the horizontal outlines of the bases of two rounded projections a few inches high, broad and long. Joints appear to have an influence in some instances and none in others. (For a cross-section of the furrows, see Fig. 3.)

In other portions of the same area where the main rock surface is free of projections similar furrows are in approximately parallel straight lines which may or may not be coincident with the stratification lines.

The two types of furrowing, especially the second one, support the proposition that a practically horizontal surface can be produced and maintained by the planing action of the sea, since the furrows can only be regarded as forms of that action.

Saucering

This section relates to the depression and to flat areas a few square yards in extent which occur at different levels in the rampart.

The traversing of the sandstones by vertical or nearly vertical joints which divide the surface into polygons of various size with the deposition of oxide of iron along and for varying distances from the joints has been noted above under the section treating of the general characteristics of the pits. The altered rock may be termed the 'brown rock' and the unaltered the 'grey rock'. (Figs. 4 and 5.)

In the planing and mechanical disintegration of the rock surface, the brown rock appears to be only slightly more resistant than the grey rock. That is well shown on the ramp, where the ribs of iron oxide along or close to the joints generally are planed level with or rise very slightly above the grey rock. Chemical weathering on the ramp, if it occurs, does not apparently affect the grey rock more than the brown rock.

However, where the surface has become practically horizontal as in the depression and the small flat areas in the rampart, then the slight irregularities of that surface would be sufficient to hold a small quantity of sea water. That water then apparently acts chemically on the grey rock but not on the brown, or at least not to the same extent. The result is that the grey rock is lowered faster than the surrounding brown rock and so very shallow basins of grey rock are formed within the polygons with low rims of brown rock on or close to the joints.

As the basins deepen more sea water collects in them and thus they may become several inches deep. The lowest part of the grey rock is from an inch or two to six or eight inches below the highest part of the rim of the brown rock and the interiors of the polygons are in many places at slightly different levels (up to 10 inches or more) owing to the unequal removal of the grey rock in the different polygons.

The basins so formed may be referred to as 'saucers' and the processes producing them as 'saucering'.

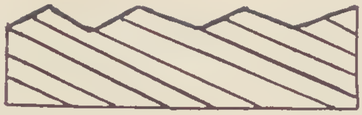
The boundary between the brown and grey rock surfaces does not follow the rectilinear shape of the polygon but tends to become roughly circular or elliptical according to the form of the polygon, this being an example of faster alteration of the corners of that figure.

The basins are prevented from reaching more than a certain depth owing to their oxide of iron rims being reduced in height by the action of the sea which, since it forms distinct grooves in those rims, must be capable of a general planing down of the surfaces of the rims. The sea also forms pits in the rims. Water-level weathering (the possibility of which is discussed in the next section) and crystallization of salts may also help in the reduction of the rims. Whatever the processes are that bring about that reduction a balance is struck between the two classes of rock by means of which the basins remain shallow.

It would seem that so long as the lowering of the grey rock in the pools is faster than or equal to the lowering of the iron rims, whether the latter be lowered by the action of the sea alone or by the sea and water-level weathering combined (with perhaps the assistance from crystallization of salts) the pools will continue in existence.

A saucer may be drained by the cutting of a groove in the iron rim at its lowest part.

It is important to note that the pools on the depression and on the small flat areas in the rampart cannot be formed as distinctive features until the rock surface is almost horizontal and, consequently, that until that surface is formed water-level weathering must act very slightly, if at all. It follows therefore that that surface must have been produced primarily by the varied planing action of the sea with the assistance (a) of the subsidiary marine factors described in this paper, (b) of ordinary sub-aerial weathering in the form of alternate wetting and drying (where there are sufficient time intervals for drying to take place), and (c) of perhaps the crystallization of sea salts.



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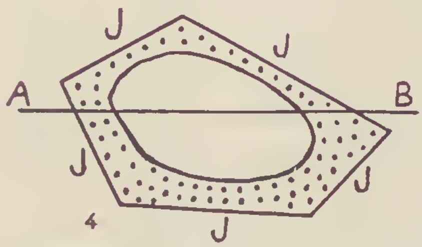

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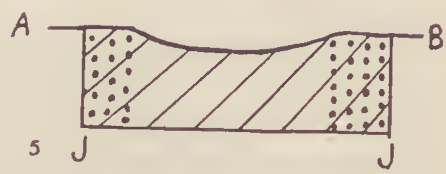

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Fig. 1.—Section across the minute furrows along the laminae of a sandstone floor. Point Grey-Erskine Platform.

Fig. 2.—Diagrammatic plan showing the minute ridges and furrows on a sandstone floor S.W. of Point Grey. Note how the ridges and furrows curve around the small projections A and B. The dotted areas represent the ridges and the unmarked areas between and following around the ridges represent the furrows.

Fig. 3.—Section across the minute furrows and ridges shown on Fig. 2. Note the rounded outlines contrasted with those of Fig. 1.

Fig. 4.—Plan of a polygon showing the development of the brown (oxide of iron) rock (dotted) at the expense of the grey rock (unmarked). The joints are marked J.

Fig. 5.—Section along the line AB of Fig. 4 showing the development of a shallow basin in the grey rock (not dotted).

Water-Level Weathering

In the writer's earlier paper on Lorne (1949) he considered that the direct planing action of the waves was the chief agent in the formation of the depression and the ramp. Wentworth's water-level weathering (1938) (the water-layer weathering of Hills, 1949) may, the present writer thought, have helped to decrease the depth of the saucers. It may be noted, as Hills (1949, p. 141) has recorded, that Bartrum and Turner (1928) and later Bartrum (1935) described the process but without giving it a definite name.

Hills (1949) considers that water-level weathering, where some Victorian platforms are composed of basalts and tuffs, or of Tertiary ferruginous sandstones or of the Jurassic rocks of which the Lorne platforms are composed, plays an important part in reducing the general level of the platforms. Edwards (1951), on the other hand, holds that for narrow platforms, such as those of Lorne, sand scour is the predominant agent, although water-level weathering has some effect.

The writer adheres to the opinion expressed by him as above stated, before the papers by Hills and Edwards were published, that wave planation was the chief cause of the smooth surfaces of the depression and the ramp. He has, however, since the publication of his own paper made further observations and has given the matter further consideration. It must be borne in mind that his conclusions as here stated relate only to the Lorne platforms.

As regards the ramp, although the iron oxide has been introduced on each side of the joints of the rocks as on the depression, there are usually no iron rims. The whole surface is generally planed level. Although owing to the absence of pools water-level weathering cannot take place, yet sub-aerial erosion (by alternate wetting and drying) could and doubtless does operate, and it would operate more on the ramp than on the depression or the rampart, because the ramp will have longer periods of dryness than either of the other two features. Crystallization of sea salts may also cause some disintegration of the rock surface. But if either of those processes so operated as a major agent patchy inequalities in the surface would doubtless be caused thereby and the ramp does not show those inequalities. It has the appearance of being steadily and smoothly planed down, and hence wave planation must be regarded as the major agent in the production of the ramp.

The only portions of the platform, therefore, on which water-levelling may act to any extent are the parts of the depression and the small flat areas in the rampart where pools occur under similar conditions.

As regards the depression, water-level weathering cannot act until the pools are formed which cannot be until a practically horizontal surface is produced by planing as shown above; and when the pools have formed water-level weathering has to compete with the planing action of the sea in its various forms. To determine, therefore, the extent of water-level weathering is difficult, but in view of the planing strength of the sea, water-level weathering must be comparatively slight.

As regards the small flat areas of the rampart the rims of the pools can scarcely ever be dry. Water-level weathering on that açcount would be even less than on the depression.

The above discussion of water-level weathering treats of the surface of the platforms as a whole. That water-level weathering perhaps assists in the removal of the pits is stated under that heading in this paper.

In conclusion, the writer desires to direct attention to the critical remarks of Douglas Johnson (1938, pp. 268-272) concerning the original statement of water-level weathering by Wentworth (1938).

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Explanation of Plate VII

Fig. 1.—Calcareous concretions of elongated form rising above the general level of the minor platform are shown in the middle distance and towards the left background. The rectilinear joints are well shown in the smooth planed surface. Pits are being removed as shown in the foreground where along or close to the joints they are being replaced by narrow shallow grooves. N.E. of St. George's River mouth.

Fig. 2.—Pits on the vertical faces of a succession of low terraces on the minor platform. Pits also occur on the flat floor in the foreground. Both series are in course of removal by the scouring and planing action of the sea. S.W. of the mouth of Reidy Creek.

Fig. 3.—Pits on a slope of about 40°. The main mass is about five feet long by two feet six inches high. The lowest six inches are not pitted since they are scoured by the waves. In the middle and left foreground are two calcareous concretions which are not pitted although pits occur above and below them. Note that pits on a slope in the right-hand lower corner are also being planed down. About 300 yards N.E. of the St. George's River mouth.